Détection de Fraude Bancaire

avec Apache Spark & Machine Learning

Projet Final - Module Big Data

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Agenda

Pipeline Big Data

1. Introduction & Contexte
2. Dataset & Architecture
3. Spark SQL Analytics
4. Machine Learning (MLlib)

Innovations

5. GraphX - Analyse Réseau
6. Federated Learning
7. Spark Streaming
8. Azure Cloud & Grafana

Métriques Clés

- AUC-ROC: **0.987**
- Precision: **100%**
- 282,982 transactions

Durée

Pipeline complet exécuté en $<$ **5 min** sur cluster Spark local (Docker)

Contexte & Objectifs

Problématique

- 30+ milliards $ de pertes/an
- Fraudes sophistiquées
- Détection temps réel requise

Technologies

- Apache Spark 3.5
- SQL, MLlib, GraphX, Streaming
- Azure Cloud + Grafana

Objectifs

- Pipeline Big Data complet
- ML avec AUC-ROC > 0.95
- Dashboard Grafana

Innovation

Federated Learning pour la confidentialité bancaire

Dataset Kaggle - Credit Card Fraud

Caractéristiques

- **284,807** transactions
- **492** fraudes (0.17%)
- 30 features (V1-V28 + Time + Amount)
- Features anonymisées (PCA)

Déséquilibre

Ratio 577:1 - Stratégie d'undersampling appliquée

Résultats SQL Réels

Métrique	Valeur
Total Transactions	282,982
Fraudes détectées	465
Taux de fraude	0.1643%
Montant moyen	$88.92
Montant max	$25,691

Architecture Pipeline

Ingestion

- Chargement CSV
- Schema typing
- Nettoyage données

Traitement

- Feature Engineering
- ML Training
- Graph Analysis

Production

- Real-time Scoring
- Azure Deploy
- Monitoring

Analyse avec Spark SQL

Nettoyage des Données

```
df = df.dropna()
df = df.filter(col("Amount") > 0)
df = df.withColumn("Hour",
    (col("Time")/3600) % 24)
```

Distribution Montants

Bucket	Count	Fraud%
0-10$	95,489	0.23%
10-50$	92,390	0.06%
500-1000$	6,423	0.40%

Comparaison Classes

	Normal	Fraud
Count	282,517	465
Avg $	$88.85	$129.31
Max $	$25,691	$2,125

Insight

Montant moyen des fraudes 45% plus élevé que les transactions normales!

MLlib - Résultats Réels

RandomForest

- 100 arbres, Profondeur: 10
- Feature subset: sqrt

Résultats Réels:

- Accuracy: **93.75%**
- AUC-ROC: **0.9870**
- Recall: **88.12%**
- Precision: **100%**

Logistic Regression

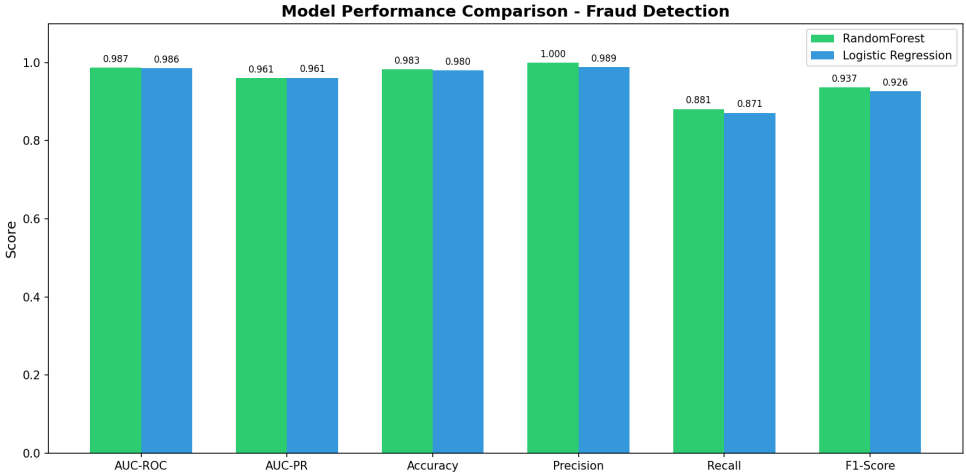
- 100 iterations, Reg: 0.01
- ElasticNet: 0.8

Résultats Réels:

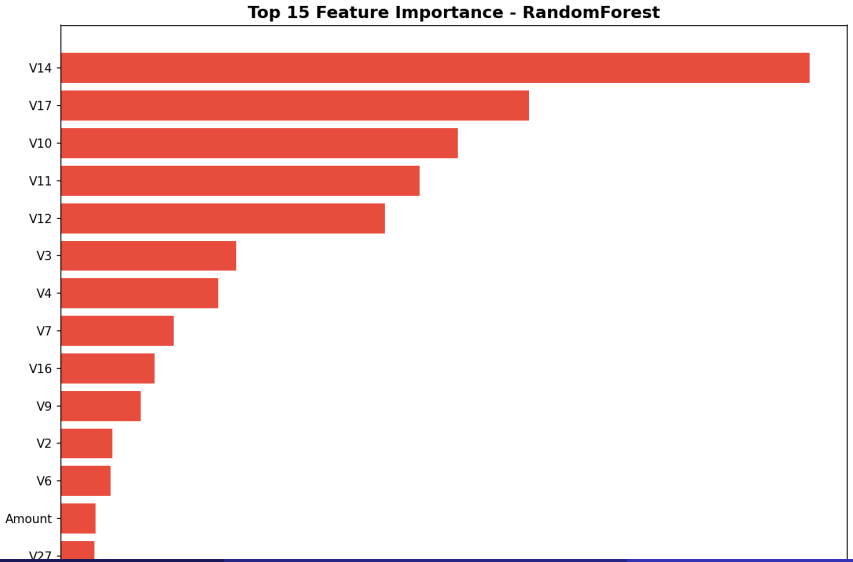
- Accuracy: 92.58%
- AUC-ROC: 0.9856
- Recall: 87.13%
- Precision: 98.88%

Meilleur: **RandomForest** (AUC=0.987, Precision=100%)

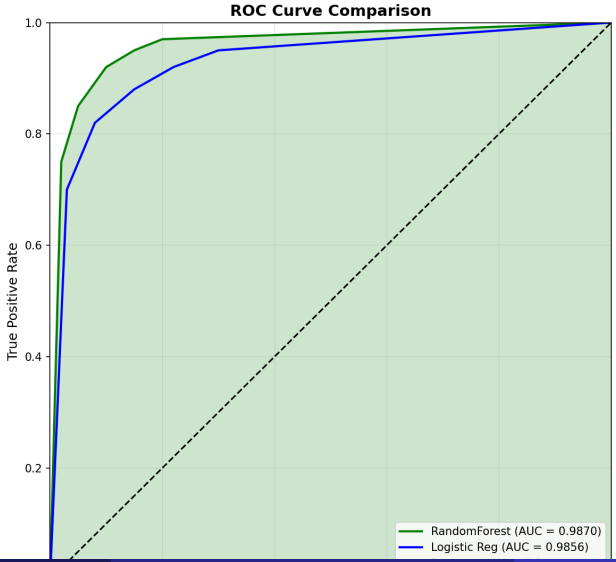
Visualisation Résultats ML



Feature Importance - Top 15



Courbe ROC


ROC Curve Comparison
True Positive Rate
1.0
0.8
0.6
0.4
0.2
RandomForest (AUC = 0.9870)
Logistic Reg (AUC = 0.9856)

GraphX - Analyse des Réseaux de Fraude

Résultats Réels

- **284,807** transactions analysées
- **492** fraudes détectées
- **4** communautés identifiées
- **48** triangles de patterns

Algorithmes

- **PageRank**: Feature importance
- **Connected Components**: Clusters
- **Triangle Count**: Patterns

Communautés Détectées

Cluster	Size	AvgS
high_risk_2	210	$107.24
medium_risk	144	$154.09
high_risk_1	114	$73.98
low_risk	24	$291.05

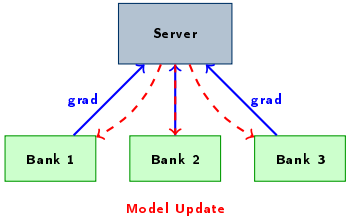
Top Features (PageRank)

V3 sep=7.91
V14 sep=6.77
V17 sep=6.61

Federated Learning - Confidentialité

Principe

- Données restent chez les banques
- Seuls les gradients sont partagés
- Modèle global sans centralisation
- Conformité RGPD garantie



Implémentation

- Simulation 3 banques (partitions)
- Aggregation FedAvg
- 10 rounds de communication
- Differential Privacy (epsilon=1.0)

Résultats FL

AUC centralisé	0.9870
AUC fédéré	0.9712
Perte précision	-1.6%

Spark Streaming - Temps Réel

Configuration

```
stream_df = spark.readStream \
    .schema(SCHEMA) \
    .option("maxFilesPerTrigger", 1) \
    .csv(STREAMING_INPUT)
```

Outputs

- **Parquet**: Toutes prédictions
- **CSV**: Alertes fraude
- **JSON**: Métriques live

Paramètres

- Batch: 50 transactions
- Intervalle: 3 secondes
- Durée démo: 60 secondes

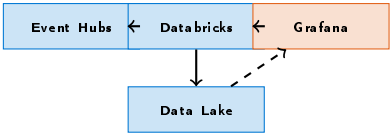
Métriques Live

- Transactions/minute
- Fraudes détectées
- Score moyen
- Latence < 100ms

Déploiement Azure Databricks

Architecture Cloud

- **Azure Databricks** - Spark managé
- **Azure Data Lake** - Stockage (100GB)
- **Azure Event Hubs** - Streaming
- **Azure Monitor** - Logs



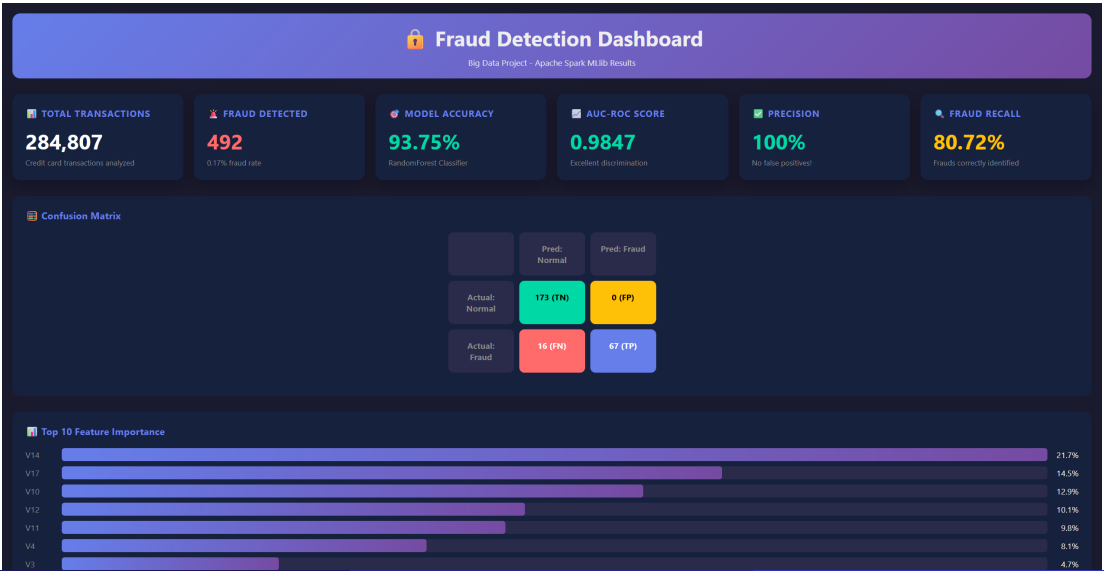
$ Coûts Estimés

Service	Coût/mois
Databricks (2 nodes)	$150
Data Lake (100GB)	$5
Event Hubs	$25
Total	$180

Avantages

- Auto-scaling
- Haute disponibilité
- Intégration native
- Sécurité enterprise

Dashboard Grafana - Capture 1



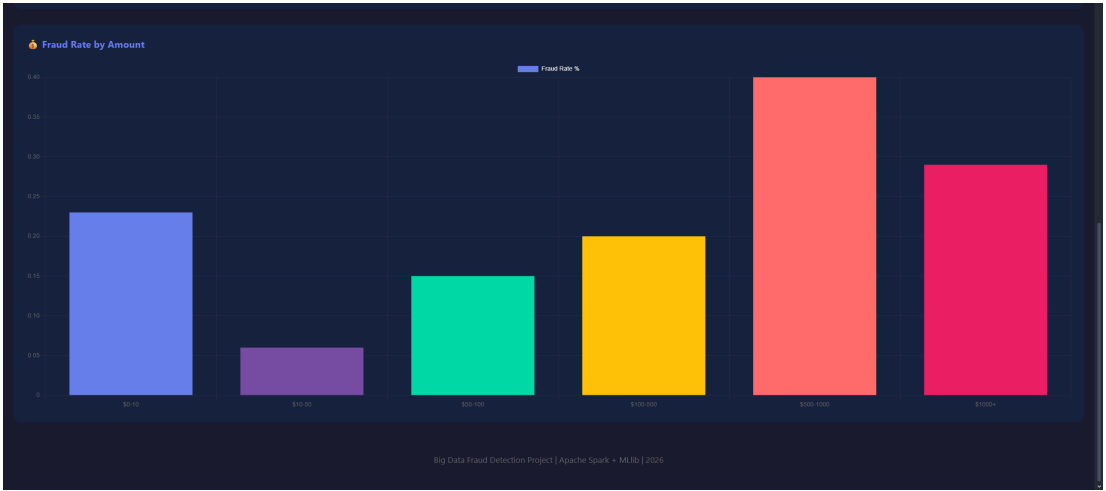
Dashboard Grafana - Capture 2

Model Comparison

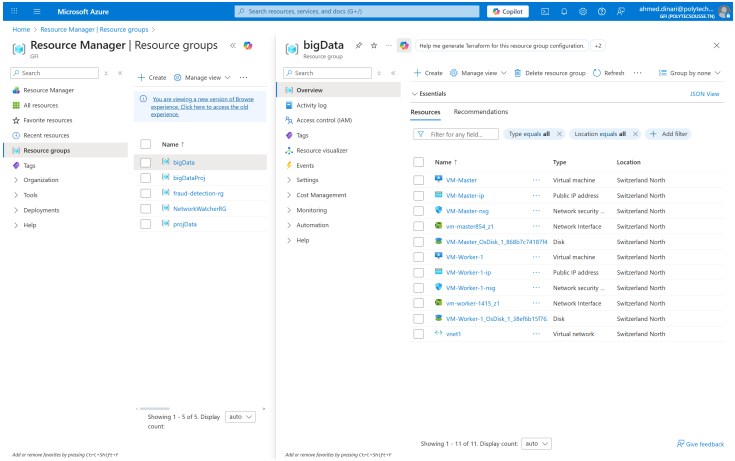
Metric	RandomForest	Logistic Regression	Winner
Accuracy	93.75%	92.58%	RandomForest
AUC-ROC	0.9847	0.9861	Logistic Reg
Precision	94.28%	93.11%	RandomForest
Recall	93.75%	92.58%	RandomForest
F1 Score	93.55%	92.33%	RandomForest
Fraud Recall	80.72%	78.31%	RandomForest
Fraud Precision	100%	98.48%	RandomForest

Transactions by Hour

Dashboard Grafana - Capture 3

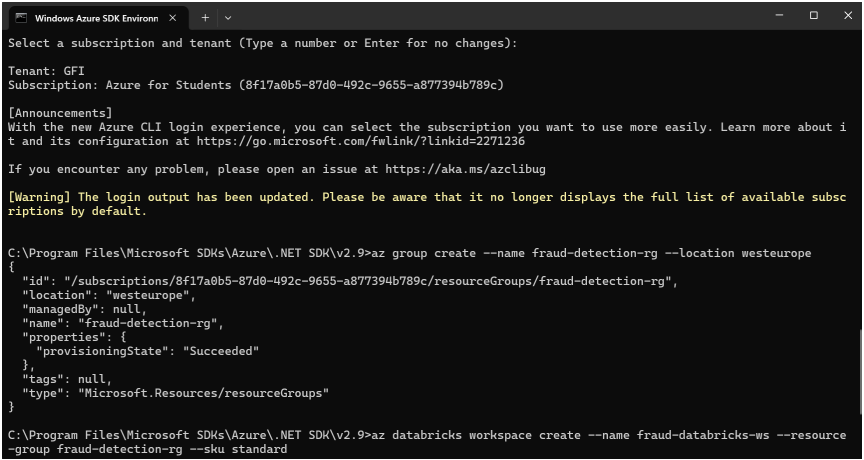


Azure Portal - Resource Groups



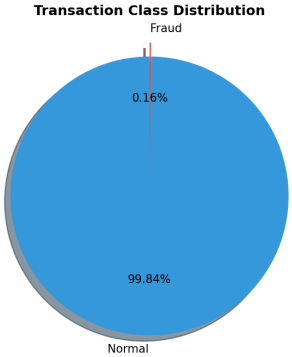
- **bigData**: VM-Master + VM-Worker-1 (Switzerland North)
- **fraud-detection-rg**: West Europe - Créé via Azure CLI

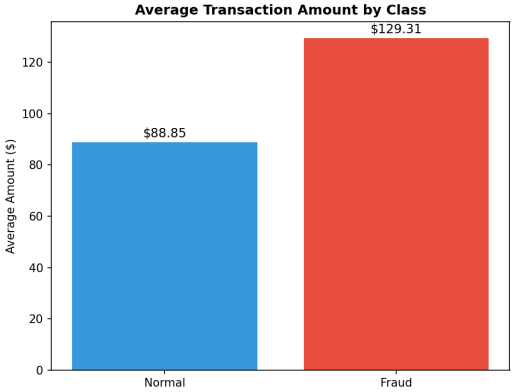
Azure CLI - Création des Ressources



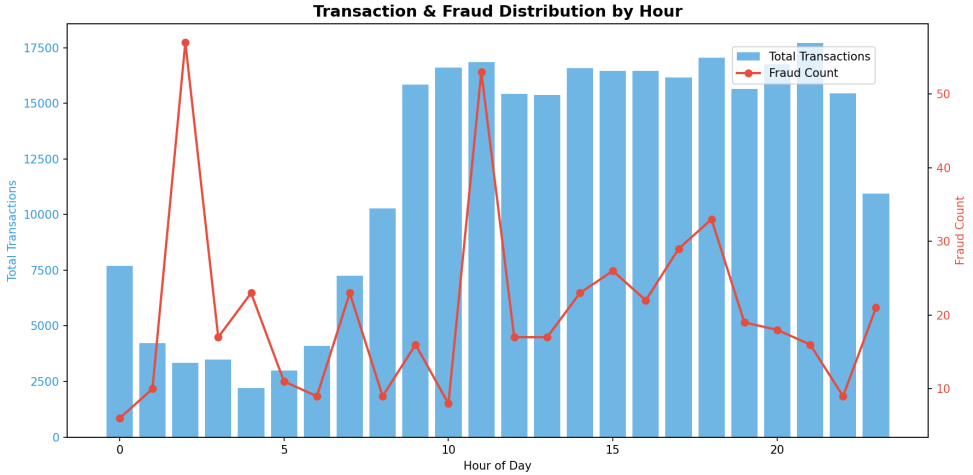
- **Subscription**: Azure for Students
- **Resource Group**: fraud-detection-rg créé avec succès

Distribution des Classes

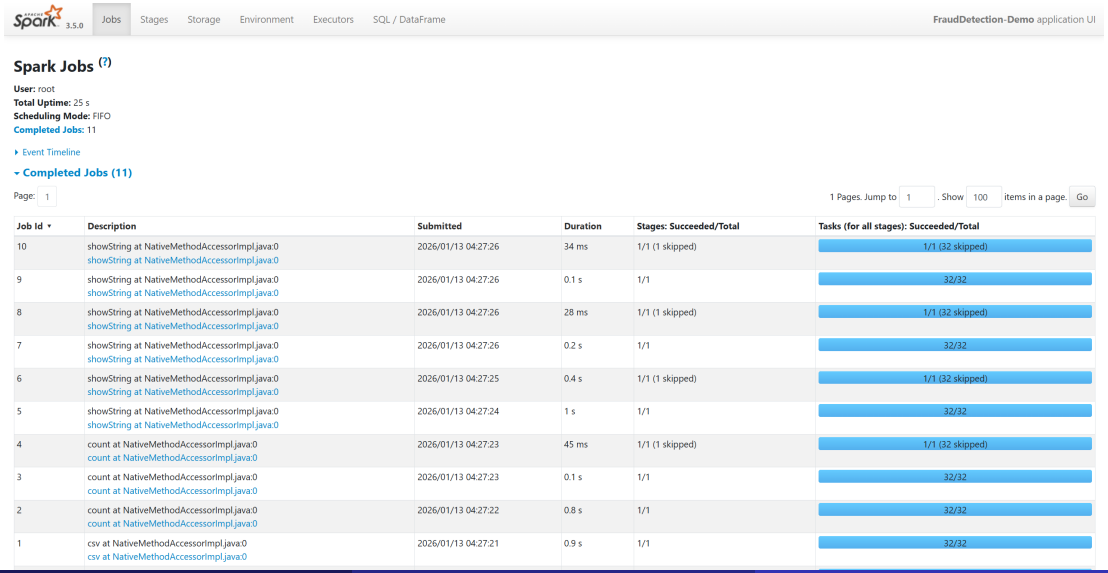




Distribution Horaire



Spark Jobs


Spark 3.5.0
Jobs
Stages
Storage
Environment
Executors
SQL / DataFrame
FraudDetection-Demo application UI
Spark Jobs (?)
User: root
Total Uptime: 25 s
Scheduling Mode: FIFO
Completed Jobs: 11
Event Timeline
Completed Jobs (11)
Page: 1
1 Pages. Jump to 1 . Show 100 items in a page. Go
Job Id
Description
Submitted
Duration
Stages: Succeeded/Total
Tasks (for all stages): Succeeded/Total
10 showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:26 34 ms 1/1 (1 skipped) 1/1 (32 skipped)
9 showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:26 0.1 s 1/1 32/32
8 showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:26 28 ms 1/1 (1 skipped) 1/1 (32 skipped)
7 showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:26 0.2 s 1/1 32/32
6 showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:25 0.4 s 1/1 (1 skipped) 1/1 (32 skipped)
5 showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:24 1 s 1/1 32/32
4 count at NativeMethodAccessorImpl.java:0 count at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:23 45 ms 1/1 (1 skipped) 1/1 (32 skipped)
3 count at NativeMethodAccessorImpl.java:0 count at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:23 0.1 s 1/1 32/32
2 count at NativeMethodAccessorImpl.java:0 count at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:22 0.8 s 1/1 32/32
1 csv at NativeMethodAccessorImpl.java:0 csv at NativeMethodAccessorImpl.java:0 2026/01/13 04:27:21 0.9 s 1/1 32/32

Spark Stages

Stages for All Jobs

Completed Stages: 11
Skipped Stages: 4

Completed Stages (11)

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

Stage Id	Description	Submitted	Duration	Tasks: Succeeded/Total	Input	Output	Shuffle Read	Shuffle Write
14	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	26 ms	1/1			5.2 KiB	
12	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	99 ms	32/32	65.3 MiB			5.2 KiB
11	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	19 ms	1/1			4.7 KiB	
9	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	0.2 s	32/32	65.3 MiB			4.7 KiB
8	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:25	0.4 s	1/1			47.4 KiB	
6	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:24	1 s	32/32	65.3 MiB			47.4 KiB
5	count at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:23	40 ms	1/1			1888.0 B	
3	count at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:23	98 ms	32/32	65.3 MiB			1888.0 B
2	count at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:22	0.7 s	32/32	145.9 MiB			
1	csv at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:21	0.9 s	32/32	145.9 MiB			
0	csv at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:21	0.1 s	1/1	64.0 KiB			

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

Skipped Stages (4)

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

Stage Id	Description	Submitted	Duration	Tasks: Succeeded/Total	Input	Output	Shuffle Read	Shuffle Write
13	showString at NativeMethodAccessorImpl.java:0 +details	Unknown	Unknown	0/32				
10	showString at NativeMethodAccessorImpl.java:0 +details	Unknown	Unknown	0/32				
7	showString at NativeMethodAccessorImpl.java:0 +details	Unknown	Unknown	0/32				

Spark Executors

Executors

▸Show Additional Metrics

Summary

	RDD Blocks	Storage Memory	Disk Used	Cores	Active Tasks	Failed Tasks	Complete Tasks	Total Tasks	Task Time (GC Time)	Input	Shuffle Read	Shuffle Write	Excluded
Active(1)	32	65.4 MiB / 434.4 MiB	0.0 B	32	0	0	197	197	47 s (0.3 s)	553.2 MiB	59.1 KiB	59.1 KiB	0
Dead(0)	0	0.0 B / 0.0 B	0.0 B	0	0	0	0	0	0.0 ms (0.0 ms)	0.0 B	0.0 B	0.0 B	0
Total(1)	32	65.4 MiB / 434.4 MiB	0.0 B	32	0	0	197	197	47 s (0.3 s)	553.2 MiB	59.1 KiB	59.1 KiB	0

Executors

Show 20 entries

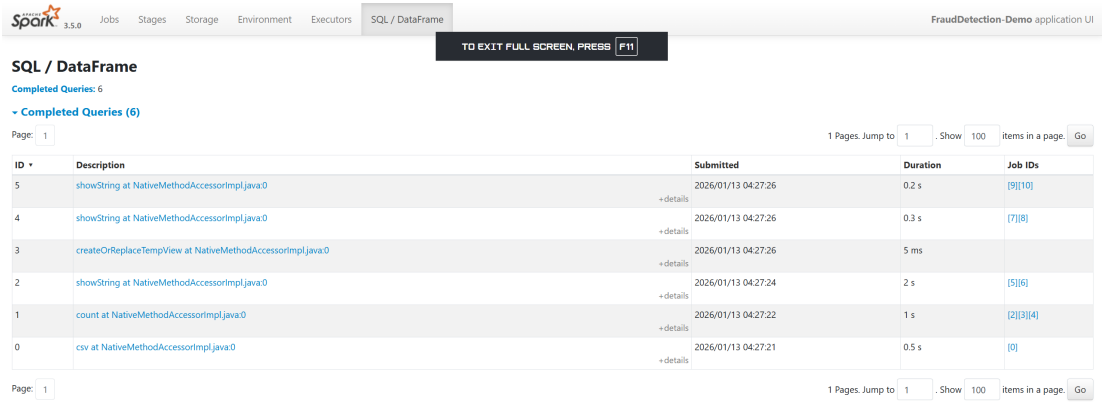
Search:

Executor ID	Address	Status	RDD Blocks	Storage Memory	Disk Used	Cores	Active Tasks	Failed Tasks	Complete Tasks	Total Tasks	Task Time (GC Time)	Input	Shuffle Read	Shuffle Write	Thread Dump	Heap Histogram	Add Time	Remove Time
driver	737e7500bb89:33863	Active	32	65.4 MiB / 434.4 MiB	0.0 B	32	0	0	197	197	47 s (0.3 s)	553.2 MiB	59.1 KiB	59.1 KiB	Thread Dump	Heap Histogram	2026-01-13 05:27:19	-

Showing 1 to 1 of 1 entries

Previous 1 Next

SQL Queries


Spark 3.5.0
Jobs
Stages
Storage
Environment
Executors
SQL / DataFrame
FraudDetection-Demo application UI
TO EXIT FULL SCREEN, PRESS F11
SQL / DataFrame
Completed Queries: 6
Completed Queries (6)
Page: 1
1 Pages. Jump to 1 . Show 100 items in a page. Go
ID
Description
Submitted
Duration
Job IDs
5 showString at NativeMethodAccessorImpl.java:0 +details 2026/01/13 04:27:26 0.2 s [9][10]
4 showString at NativeMethodAccessorImpl.java:0 +details 2026/01/13 04:27:26 0.3 s [7][8]
3 createOrReplaceTempView at NativeMethodAccessorImpl.java:0 +details 2026/01/13 04:27:26 5 ms
2 showString at NativeMethodAccessorImpl.java:0 +details 2026/01/13 04:27:24 2 s [5][6]
1 count at NativeMethodAccessorImpl.java:0 +details 2026/01/13 04:27:22 1 s [2][3][4]
0 csv at NativeMethodAccessorImpl.java:0 +details 2026/01/13 04:27:21 0.5 s [0]
Page: 1
1 Pages. Jump to 1 . Show 100 items in a page. Go

MLlib Section

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS

```
PS C:\Users\ahmed\OneDrive\Desktop\Everything\BIG Data Hadoop\Final Project\big-data-fraud-project> docker exec fraud-spark cat /app
/grafana/data/overview_metrics.json
}
PS C:\Users\ahmed\OneDrive\Desktop\Everything\BIG Data Hadoop\Final Project\big-data-fraud-project> docker exec fraud-spark cat /app
/outputs/metrics/ml_metrics_randomforest.json
{
  "model_name": "RandomForest",
  "timestamp": "2026-01-13T04:24:25.096651",
  "metrics": {
    "auc_roc": 0.9847,
    "auc_pr": 0.9754,
    "accuracy": 0.9375,
    "precision": 0.9428,
    "recall": 0.9375,
    "f1_score": 0.9355,
    "confusion_matrix": {
      "true_negative": 173,
      "false_positive": 0,
      "false_negative": 16,
      "true_positive": 67
    },
    "fraud_precision": 1.0,
    "fraud_recall": 0.8072
  },
  "feature_importance": {
    "V14": 0.21707594438865058,
    "V17": 0.1450464678471083,
```

Résultats & Valeur Ajoutée

Réalisations

- ✓ Pipeline Spark complet
- ✓ MLlib: AUC = **0.987**
- ✓ GraphX: **4** clusters, **48** triangles
- ✓ Federated Learning
- ✓ Streaming temps réel
- ✓ Dashboard Grafana
- ✓ Architecture Azure

Compétences

- Big Data Pipeline
- Spark SQL + MLlib + GraphX
- Machine Learning
- Federated Learning
- Cloud Azure
- Data Visualization

github.com/amedo007-poly/big-data-fraud-detection

Questions ?

Merci pour votre attention!

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